Hazardous Materials Flow Analysis
Phase One – Upstate South Carolina

Final Project Report

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Hazardous Materials Flow Analysis
Phase One – Upstate South Carolina

I. Introduction and Purpose

This report details the purpose, method, and results of a hazardous material (hazmat) commodity flow analysis commissioned by the South Carolina Emergency Preparedness Division for the state's northern interstate highways. Recent events such as the gasoline tanker crash on U.S. 521 in May 1999 (cover photo) underscore the importance of identifying the type, quantity, volume, and spatial distribution of hazardous materials travelling throughout South Carolina. This accident resulted in the death of the driver and the contamination of a nearby creek. In relative terms these particular losses are small, but the potential risk of damage to people, property, and the environment may be much greater depending upon the type and quantity of the material carried, and the time and location of the incident.

Provided within this report are the results from a hazardous materials placard survey and a vehicle manifest survey conducted from January 1999 through June 1999 by the Hazards Research Lab at the University of South Carolina. Similar attempts at understanding the risk from hazardous materials transport elsewhere are limited (Mills and Neuhauser, 1998; Pine *et al.*, 1998; Cutter and Ji, 1997; Mitchelson *et al.*, 1995). Prior to this present analysis little was known about the patterns of hazardous materials flows within the South Carolina. While this report is a crucial first step in providing empirical estimates of hazardous materials flows within the state, addressing whether or not these types of hazardous materials accidents are preventable is beyond the scope of this study. Our results, however, should provide emergency officials and other responders with a baseline assessment of South Carolina's Upstate highways to improve preparedness and response capabilities to handle these events when they do occur.

II. South Carolina's Upstate Interstate Highways

Three interstate highways provide the focus for this hazmat commodity flow study, Interstates 26, 85, and 385 (Figure 1). Interstate 26 exists mostly within South Carolina (108 miles) before concluding near Asheville, North Carolina. The focus of this study is on the Upstate portion of Interstate 26 north of Columbia. Urban population centers along this corridor include Columbia (232,000), Newberry (25,000), Clinton (15,000), and Spartanburg (50,000). The interstate passes through Lexington, Laurens, Newberry, Richland, and Spartanburg counties.

Interstate 85, originating in Petersburg, Virginia, and terminating in Montgomery, Alabama, bisects five South Carolina counties (Anderson, Cherokee, Greenville, Oconee, and Spartanburg). Greenville County is the most populous county in the state with more than 320,000 residents. Located within the fast-growing Upstate region, the Interstate 85 corridor has seen an increase in traffic congestion and volume during the last decade. Much of the state's potential threat from hazmat incidents is expected from this particular interstate.

Connecting I-26 and I-85 is the 42-mile Interstate 385. An off-shoot of Interstate 26 in Clinton, South Carolina, Interstate 385 continues north across Interstate 85 and concludes in downtown Greenville. This interstate passes through Laurens and Greenville counties.

III. Data and Methods

The data for this study were collected using two different methods: a placard survey of trucks and a vehicle manifest survey of hazardous materials haulers. The placard survey was conducted six times at five different locations over a six-month period (January-June 1999). The vehicle manifest survey was conducted at three designated weigh stations twice during the study period.

Placard Survey

A field survey instrument was developed during late fall 1998 and then pre-tested on I-26 in Columbia on December 22, 1998. The field test resulted in minor changes to the survey instrument to facilitate data collection. Table 1 details the variables that were collected when available.

Table 1 Placard Survey Variables

Variable (Pre-determined)	Variable (Collected in Field)
Time of Day	Hazardous Class Number
Day of Week	Material Guide Number
Survey Date	Carrier Name
Interstate	Vehicle Type
Location	
Mile Marker	
Direction	
Survey Team	

Survey sites for the placard study were selected in consultation with the South Carolina Office of Emergency Preparedness. They were based on accessibility, visibility, and safety considerations for the research teams (Figure 1, Table 2). A field data collection method loosely based on Mitchelson et al. (1995) was developed with three two-day field visits executed during the winter and spring of 1999. Five two-member teams worked back-to-back, six-hour shifts at five sites. We were restricted to daylight hours only, so the shifts ran from 6a.m. to 6 p.m. After the first six hour shift, the teams moved to observe the opposite traffic direction. A total of 360 observation hours took place. The sites were surveyed at different days of the week to insure that we had both peak and off-peak traffic. Further details of these site visits are provided in Table 3.

Table 2 Placard Survey Sites

Site #	Interstate	Location	Mile Marker
1	I-26	Parking Area	5; 10
2	I-85	Rest Area	17; 22
3	I-85	Parking Area	87
4	I-385	Rest Area	5
5	I-26	Parking Area	85; 88

Table 3 Placard Survey Site Visits

Date	Day	Conditions	Shifts	Observation Hours*
1-22-99	Friday	Overcast	6am – 6pm	60
1-23-99	Saturday	Thunderstorms	6am – 6pm	60
3-8-99	Monday	Overcast	6am – 6pm	60
3-9-99	Tuesday	Snowstorms	6am – 6pm	60
5-19-99	Wednesday	Sunny	6am – 6pm	60
5-20-99	Thursday	Sunny	6am – 6pm	60
			Total	360

*Observation hours may be slightly less due to individual site constraints such as low visibility.

Every team kept track of each 5-axle (18-wheel) vehicle by hand-held counter to get an overall count of vehicular traffic. Smaller vehicles were included in the overall count if they had a placard. For further verification of the truck traffic totals, the South Carolina Department of Transportation laid count strips (permanent and temporary) for a period of 24 hours before and after each site visit (Table 4).

Table 4 SCDOT Count Strip Placement

Site #	Interstate	Location	Mile Marker	Strip Type
1	I-26	North Carolina State Line	3	Permanent Hook-up
2	I-85	Anderson County	17	Permanent Hook-up
3	I-85	Bryant Road	76	Permanent Hook-up
4	I-385	Barksdale – Ora	10	Temporary Hook-up
5	I-26	White Rock	94	Permanent Hook-up

Vehicle Manifest Survey

Manifest surveys were conducted at the three weigh stations within the study area: Interstate 85 at mile marker 9 – Townville Scales (Northbound only), Interstate 26 at mile marker 81 – Peak Scales (Eastbound), and Interstate 26 at mile marker 88 – Richland Scales (Westbound). Each site was visited twice for an eight-hour shift during the study period (Table 5). With the assistance of the South Carolina State Transport Police, placarded trucks were waived off the interstate following their initial weigh-in. Hazard Research Lab members quickly surveyed (3-5 minutes) the driver's manifests collecting the requisite data (Table 6).

Table 5 Vehicle Manifest Survey Site Visits

Date	Scale Location	Day	Conditions	Shifts	Observation Hours
2-22-99	Peak; Richland	Monday	Sunny	7am–3pm; 12pm–8pm	16
5-25-99	Peak; Richland	Tuesday	Sunny	7am–3pm; 12pm–8pm	16
6-1-99	Townville	Tuesday	Overcast	12pm–8pm	8
6-2-99	Townville	Wednesday	Overcast	7am–3pm	8
				Total	48

Table 6 Vehicle Manifest Survey Variables

Variable (Pre-determined)	Variable (Collected in Field)
Time of Day	Hazardous Class Number
Day of Week	Material Guide Number
Survey Date	Carrier Name
Interstate	Carrier Address (home base)
Location	Amount of Chemical Transported
Mile Marker	Vehicle Type
Direction	Vehicle (cargo) origin
Survey Team	Vehicle destination
	Basic Route Driven
	NAERG safety guide possession

Data Entry

All field data were geocoded and manually entered by the Hazards Research Lab assistants. A relational database was constructed in Microsoft's Access for subsequent use in statistical and geographical analyses. Additional data added in the Hazards Research Lab after the field visits included evacuation distances for each chemical (NAERG, 1996), Chemical Abstracts Service (CAS) registry numbers, and the truck counts provided by the South Carolina Department of Transportation. The analysis and results presented in this final report were generated using Microsoft Access and Excel software, and ESRI's ArcView GIS.

Data Reliability and Limitations

The three primary sources of data for this report – the placard survey, the manifest survey, and the SCDOT axle counts – are constrained by data limitations including human error and machine failures. First and foremost, the data in this report must be considered a conservative estimate of the interstate truck traffic and hazardous materials flows. Placarded vehicles escaped detection during both placard and manifest survey visits. Other vehicles carrying hazardous materials failed to display placards and went unnoticed by the survey team. On the placard survey, hazardous class numbers may have been incorrectly identified or vehicles with more than one hazardous class may have been documented as carrying only one hazardous material. The manifest surveys, given the direct contact between surveyor and vehicle/driver, should carry greater reliability.

In some instances the SCDOT count strip units failed to perform, creating data reliability problems for truck counts for some of our observations. While placed as close to the survey sites highway before being documented by a survey team. How often this occurred is unknown. The hand-held counts serve as another independent check on the truck counts. Despite these caveats, we believe that the data collection method has produced a robust and reliable dataset.

IV. Analysis and Results

Data Sensitivity Analyses

To test the accuracy of our hand-held vehicle counts during our sampling period, we compared them to count strip data supplied by SCDOT. As previously mentioned, SCDOT data often was problematic. In a couple of instances, the machine counter failed and data were lost for that recording period. To compensate, SCDOT provided count strip data for the same location but it was from a subsequent week on different days. In another instance when the machine failed, we were provided data for the same days and month but from 1998. Finally, in one instance the count strips were located in such a manner that there were exits between the count strips and our sampling location.

A sensitivity analysis between the SCDOT counts and the hand counters was conducted. A number of statistical tests were run to see if there were any significant differences between the two counting methods. ***No statistically significant differences (with a 95% confidence level) were found between our traffic counts and those of SCDOT for any of the study sites or for any of the time periods*** (Table 7). Therefore, we are able to extrapolate the ratio of hazmat to regular truck traffic from the SCDOT counts for the entire 24 hour period to gain a better understanding of the flow of hazmat trucks in the Upstate.

Table 7
Comparison of Truck Flow Data Collected by the Hazards Research Lab and by the SC Department of Transportation*
(Trucks per minute)

	I-26 Mile Marker 3	I-85 Mile Marker 17	I-85 Mile Marker 76	I-385 Mile Marker 10	I-26 Mile Marker 94
January 22 & 23					
SCDOT count	1.029	2.956	2.875	0.697	1.426
HRL count	1.385	3.062	3.765	0.707	1.329
T-value**	0.067	0.751	0.041	0.929	0.676
March 8 & 9					
SCDOT count	1.778	3.516	3.891	1.081	1.833
HRL count	1.576	4.312	5.907	0.984	2.033
T-value	0.063	0.006	0.000	0.168	0.145
May 19 & 20					
SCDOT count	1.791	4.251	4.447	1.223	N/A
HRL count	1.796	4.344	6.463	1.223	N/A
T-value	0.963	0.663	0.000	0.916	N/A

* The countstrip data for Milemarker 3 for March was actually collected March 22-23, 1999. Data for MM 10 was actually collected March 9-10, 1998. Data are not available for March 19-20 for MM 94 due to faulty equipment.
**T-values greater than 2.1 are significant at the p=.05 level.
N/A could not be computed or data were unavailable

Truck Frequency and Hazardous Materials Counts

The first component of the analysis of traffic frequency was to compare the flow of regular truck (18-wheeler) and hazmat traffic on each interstate using our raw counts by interstate segment. I-85 has the highest truck traffic flow, almost twice that of the other two interstate segments (Figure 2a). Peak traffic counts on I-85 occurred in early afternoon (1-2 p.m.) with more than 300 trucks per hour. There is a relatively steady flow of trucks on I-85 from 10 a.m. to 4 p.m. with a slight dip at 11 a.m. Traffic along I-26 is fairly steady throughout the day, but peaks around 10 a.m. The number of trucks average slightly more than 100 per hour for most of the day (9 a.m. to 3 p.m.). The volume of traffic on I-385 is significantly less and peaks at 10 a.m. with a noticeable dip at noon for lunch breaks.

The hourly flow of hazmat shows a different pattern (Figure 2b). On I-26, hazmat traffic peaked at 9 a.m. with a secondary peak at 1 p.m. (1300 hours). I-385 also had two peaks (10 a.m. and 2 p.m.), both of which were delayed by one hour from the peak times on I-26. I-85 had four noticeable peaks at 8:00 a.m., 10:00 a.m., 1:00 p.m., and 4:00 p.m., with the highest peak in hazmat flow at 4.p. (16:00 hours).

In developing an overall summary of traffic flow we included the flow data from the weigh stations to provide additional sampling points. The latter time periods (after 6 p.m.) reflect the use of weigh station counts. The aggregated data (Figure 3) show a gradual rise in volume from 6 a.m. with an initial peak at 10 a.m. and a secondary peak at 2 p.m. (1400 hours). Hazmat flows are quite consistent with peaks between 8-10 a.m. and 1-2 p.m. For the entire sample, the ratio of hazmat carriers to regular truck traffic is roughly 1 hazmat per 21 trucks. This varies by individual site as well as throughout the day. For example, the ratio of hazmat carriers to trucks is lowest at 8 a.m. (17.5) and highest at 3 p.m. (25.5). Although I-85 received the most traffic, hazmat carriers involved a larger percentage of truck traffic on I-26 (Figures 4-6) than on any other interstate.

Finally, there is some directional bias in the truck traffic. I-26, for example has a slightly larger volume of both truck and hazmat traffic moving West, towards the Upstate. I-385 has a larger volume of trucks traveling North, but a higher volume of hazmat carriers traveling South. I-85 has more truck and hazmat traffic traveling South (Table 8). In examining the data for each survey location some interesting patterns emerged. For example, we surveyed two locations on I-85, one near the Georgia border and the other near the North Carolina border. Looking at traffic flow in each direction, we found a larger volume of trucks and hazmat carriers were traveling South on I-85 near the Georgia field site, while a larger volume of trucks were traveling North near the North Carolina border. However, the frequency of hazmat carriers was higher traveling South at the North Carolina border site. According to the data, there was more traffic leaving South Carolina then entering on I-85. For 1-26 we found that both field sites had larger volumes of trucks and hazmat carriers traveling West toward the Upstate. We suspect that these carriers connected with I-85 and traveled South which accounts for the larger volumes of trucks and hazmat traffic at the Georgia border field site.

Table 8 Direction of Traffic Flows
(Number of carriers per hour)

Interstate/Location	Direction				Average
	East	West	North	South	
I-385					
Truck			57.0	55.3	56.1
Hazmat			2.2	2.3	2.25
I-85 (Total)					
Truck			261.0	268.9	265.0
Hazmat			9.6	10.1	9.8
I-85 (MM 17)					
Truck			206.0	229.7	217.9
Hazmat			8.7	9.6	9.2
I-85 (MM 76)					
Truck			321.0	309.2	314.9
Hazmat			10.6	10.7	10.7
I-85 (Weigh station)					
Truck			262.0		
Hazmat			8.9		
I-26 (Total)					
Truck	96.9	102.7			99.8
Hazmat	7.2	8.5			7.8
I-26 (MM 3)					
Truck	83.8	93.8			89.8
Hazmat	9.6	10.5			10.1
I-26 (MM 94)					
Truck	108.2	111.9			110.0
Hazmat	5.1	6.4			5.7
I-26 (Weigh station)					
Truck	127.7	151.5			139.6
Hazmat	7.6	4.1			5.9
Total Trucks	**96.9**	**102.7**	**196.4**	**197.0**	**158.1**
Total Hazmats	**7.2**	**8.5**	**7.3**	**7.5**	**7.6**

Weekly and Seasonal Variability in Traffic Flows

Traffic flows are greatest on Wednesdays and Thursdays with significant drops during the weekend (Saturday). Trucks carrying hazardous materials most often are found on Thursday (Table 9). Regionally, Thursday was the peak day for truck traffic for both I-85 and I-385, while traffic counts on I-26 were highest on Wednesday (Figure 7a).

I-85 has the highest frequency of hazmat carriers peaking on Thursday with an average of 12.4 hazmat carriers/hour (Figure 7b). In fact, I-85 had the highest hazmat traffic on every day except Saturday, when I-26 had the highest. I-385 hazmat traffic is highest on Thursdays as well (3.2 hazmats/hour) with a secondary peak on Monday (3.1 hazmats/hour). The weekly pattern on I-26 is quite different. The highest frequency of hazmat carriers is on Monday (9.3 hazmats/hour) although Wednesday and Friday are a close second (8.8 hazmats/hour). Hazmat flows are lowest on Tuesday for 1-26 and on Saturday for both I-385.

Table 9 Weekly Variation in Traffic Flows (Vehicles/hour)

Day	Regular	Hazmat
Monday	167.7	7.9
Tuesday	163.9	6.8
Wednesday	197.6	8.5
Thursday	188.4	9.0
Friday	161.0	7.7
Saturday	71.1	4.7

There is a distinct seasonality to traffic flows in the Upstate. Overall truck traffic increased from January to May for all three interstate segments with the greatest increase occurring from January to March for both I-85 (52% increase) and I-26 (37% increase). There were small increases (less than 5%) in overall truck traffic on I-385 (Figure 8a). Hazmat flows also show increases from January onward (Figure 8b).

With the inclusion of the weigh station data, we get a better picture of the seasonality of truck traffic and hazmat carriers (Figure 9). There is a steady increase in truck traffic in the upstate from January to June. The trend for hazmat carriers is similar with the exception of February where a small decrease in hazmat flow occurred (Table 10). However, the ratio of hazmats to trucks is highest in January because of the lower overall truck traffic.

Table 10 Seasonality of Trucks and Hazmats (Number per Hour)

Month	Trucks	Hazmats	Ratio Hazmat to Truck
January	116.9	6.3	.054
February	138.8	5.9	.042
March	168.0	7.7	.046
May	181.6	8.3	.046
June	262.0	8.9	.034

Type and Amount of Transported Materials

Utilizing both placard and weigh station data, we found the most frequently transported hazardous material was gasoline, followed by propane and diesel fuel. These three substances constitute close to half of all the hazmat traffic in this survey (Table 11). Regionally, gasoline was the most frequently observed substance at all three interstates. The next most frequent hazardous material was propane for both I-26 and I-385. However, the second highest hazmat on I-85 was batteries, a corrosive substance, due to the heavy traffic from the Autozone facility in Lavonia, GA. Batteries were the third ranked material for I-385 as well.

Table 11 Most Frequently Transported Hazardous Materials

DOT ID	Chemical	Total		Interstate 26		Interstate 385		Interstate 85	
		No.	Pct	Number	Percent	Number	Percent	Number	Percent
1203	Gasoline	713	32.8	470	42.0	31	25.6	212	22.7
1075	Propane	185	8.5	126	11.3	25	20.7	34	3.6
1933	Fuel oil	130	6.0	60	5.4	11	9.1	59	6.3
1977	Liquid nitrogen	100	4.6	31	2.8	9	7.4	60	6.4
3256	Flammable liquids	98	4.5	96	8.6	0	0.0	2	0.2
2794	Batteries	95	4.4	21	1.9	13	10.7	61	6.5
3257	High temperature liquids	80	3.7	60	5.4	1	0.8	19	2.0
3082	Liquid hazardous waste	70	3.2	19	1.7	0	0.0	51	5.5
1073	Liquid oxygen	54	2.5	29	2.6	0	0.0	25	2.7
1866	Resin solid	35	1.6	14	1.3	1	0.8	20	2.1
2187	Liquid carbon dioxide	25	1.1	8	0.7	0	0.0	17	1.8
1824	Sodium hydroxide solution	23	1.1	7	0.6	0	0.0	16	1.7

While gasoline placards (DOT 1203) were observed more often than propane (DOT 1075), there was a larger amount of propane traversing interstates in South Carolina according to our weigh station data. Although carriers transporting batteries were frequently counted, they did not have large amounts in their load, causing batteries to rank thirteenth in the volume or amount of hazmat material (Table 12).

Finally, the hazardous material was categorized by class to assess the relative frequency of transport for each of them. Class 3, flammable liquids, was the most frequently observed material on all three interstates comprising half of all the hazmat traffic (Figure 10). This is primarily due to the large number of gasoline trucks. Class 8, corrosive materials (18.2%) was the second most frequently transported material, followed by Class 2, flammable gases (18.1%).

Table 12 Most Frequently Transported Hazardous Materials by Weight/Volume Based on Weigh Station Data

DOT #	Chemical Name	Amount (lbs)	% Total
1075	Propane	1,406,218	18.8
1203	Gasoline	768,841	10.3
3256	High temperature flammable liquid	690,480	9.3
1073	Oxygen, liquid	566,750	7.6
1977	Nitrogen, liquid	482,900	6.5
3082	Liquid hazardous waste	319,492	4.3
1993	Fuel oil, diesel fuel, combustible liquids	300,256	4.0
3257	High temperature liquids	248,240	3.3
1230	Methanol	169,186	2.3
1951	Argon, liquid	159,320	2.1
1263	Paint	156,200	2.1
3264	Corrosive liquids	140,835	1.9
2794	Batteries	138,444	1.9
1866	Resin solid	127,158	1.7
2581	Aluminum chloride, solution	125,260	1.7
1208	Hexanes	90,000	1.2
3077	Solid hazardous waste	86,000	1.2

There were some regional variations with all hazmat classes observed on both I-26 and I-85 (Figures 11-13). Classes 1 (explosives), 5 (oxidizers and organic peroxides), 6 (toxic materials and infectious substances), and 7 (radioactive materials) were not observed on I-385.
Data from the weigh stations shows that Class 3 substances comprise 38.2% of volume of hazmat materials transported, followed by Class 2 (flammable gases) at 34% and Class 8 corrosive materials (18.4%) (Table 13)

Table 13 Most Frequent Amount of Transported Materials by Hazard Class

Hazmat Class	Amount (lbs)	% Total
1: explosives	32,574	0.4
2: gases	2,797,996	34.0
3: flammable/combustible liquids	3,148,134	38.2
4: flammable solids	50,771	0.6
5: oxidizers and organic peroxides	136,529	1.7
6: toxic materials/infectious	137,440	1.7
7: radioactive	11,625	0.1
8: corrosives	1,517,081	18.4
9: miscellaneous	405,492	4.9
Biohazard	--	--
Dangerous	--	--
Hot	--	--

Origins and Destinations

Origin and destination data was gathered from the survey of placarded trucks at the weigh station on I-26 and I-85. Data were collected for both directions of traffic at the I-26 station, but only for northbound traffic at the I-85 weigh station. The top three origins for carriers sampled at the I-26 weigh station were Spartanburg, Lexington, and Lavonia, Georgia. Autozone was the single point of origin in Lavonia, Georgia, (Table 14). For I-85, the top three points of origin were Atlanta, Conyers, and Lavonia, all in Georgia.

Table 14 Origination of Hazardous Material Transportation Flows

Place of Origin/ Company	Number of Hazmat Carriers			
	I-85 North	I-26 East	I-26 West	% of all trips
Spartanburg				
Air Liquide		4	3	25.9
Van Waters and Rogers		2	2	14.8
Hess		3		11.1
Freeman Gas Co.		2		7.4
Carolina Wholesale Gas Co.		2		7.4
BP		1		3.7
APC		1		3.7
Unknown	1	4	2	25.9
Lexington				
Dixie Pipeline		9	6	78.9
Amerigas			1	5.2
Safety-Kleen			1	5.2
Propane Transport Intl.		1		5.2
Unknown			1	5.2
Lavonia, GA				
Autozone	11	9	2	100.0
Atlanta, GA				
Unknown	7			100.0
Conyers, GA				
Unknown	6			100.0

Most of the hazmat carriers originating in Lavonia that were monitored at the I-26 weigh station were headed to the low country (Figure 14). However, Autozone trucks from Lavonia, monitored at the I-85 weigh station were flow-through traffic (with the exception of one delivery in Spartanburg) (Figure 15). Most of the carriers originating in Lexington were travelling to the upstate (Figure 16). From Spartanburg as the point of origin, hazmat carriers monitored on I-26 were headed predominately toward the Midlands and Charleston, with some out of state destinations (Figure 17). Hazmat carriers originating in Conyers delivered to the Upstate, North Carolina, and Ohio (Figure 18). Finally, carriers originating in Atlanta were traveling through South Carolina with final destinations in Canada and the Charlotte, NC region (Figure 19).

A slightly different spatial pattern arises when the top South Carolina destinations are plotted. The top five destination points for hazmat carriers monitored on I-26 were Columbia, Florence, Charleston, Spartanburg, and Greenville (Figures 20-24). For the Columbia destination, the majority of carriers originated in the Upstate or out of state. The majority of from Spartanburg, Lavonia, Georgia, and Waynesville, NC. The Charleston destination site received traffic from Spartanburg and other Upstate origins as well as out of state (particularly Tennessee). There were no recorded hazmat carriers traveling from the Midlands or from Georgia to Charleston, which simply could be a function of the location where the data were collected. As destination points, Spartanburg and Greenville received the largest number of hazmat carriers from Lexington in addition to out-of-state carriers. There is a secondary flow from Marlboro and Richland counties to Spartanburg.

The I-85 weigh station was located near the Georgia border and only the northbound traffic was monitored. The top two destinations were Charlotte and Greenville. The majority of hazmat traffic to Charlotte originated in Atlanta and other locations in Georgia (Figure 25). There was no locally (e.g. South Carolina) generated flow. For the Greenville destination, most of the hazmat flow was from out of state, especially Alabama and Georgia (Figure 26).

Extrapolated Estimates of Hazmat Flows

Working from the SCDOT countstrip data and our hazmat counts, we estimated the total number of hazmat carriers for a 24-hour period for each interstate segment. For all segments, 18-wheeler traffic is greatest between 11 a.m. and 3 p.m. averaging more than 150 trucks per hour. Traffic is lowest between 2-5 a.m. Hazmat carriers show a different timing depending on interstate segment. For I-385, hazmat carriers peak between 10 a.m.-3 p.m. with approximately 3 per hour and then gradually taper off to one or less per hour overnight (9 p.m.-5 a.m.). For I-26, there is a rapid acceleration in the number of trucks from the overnight low, peaking between 12-1 p.m. with more than 10 hazmat trucks per hour and then gradually tapering off in the afternoon and evening. On 1-85, the low point in hazmat traffic is between 2-5 a.m. with a very gradual rise during the morning hours. The peak in hazmat traffic is later on I-85 (1 p.m., 3 p.m.) than any other segment with a very gradual decline in the late afternoon and evening hours (Figure 27).

The relative proportion of hazmat carriers to total truck traffic provides yet another indication on the potential threats of a hazardous material spill. While the frequency of hazmat carriers coincides with the greatest frequency of truck traffic, there may be other times during the day when the percentage of hazmat carriers is greatest. Table 15 shows the proportion of hazmat carriers to total trucks by hour for each of the interstate segments. Notice the percentages of hazmat carriers for I-26 are almost double the percentages for I-85 and I-385. The highest ratio of hazmat carriers to trucks for I-26 occurs at night (between 10 p.m. and midnight). On the other hand, I-85 and I-385 have the highest ratio of hazmat to truck traffic in the early morning (2 a.m. to 4 a.m.).

Table 15 Ratio of Hazmat Carriers to Total Truck Traffic by Hour Based on Extrapolated Data (expressed as %)

Time	I-26	I-385	I-85
0:00	9.43	4.18	3.91
1:00	9.41	3.80	3.94
2:00	9.40	5.00	3.96
3:00	9.37	4.90	3.94
4:00	9.30	4.12	3.89
5:00	9.13	3.44	3.93
6:00	8.91	3.79	3.91
7:00	9.13	3.77	3.90
8:00	9.05	4.11	3.94
9:00	9.39	3.94	3.92
10:00	9.36	4.01	3.89
11:00	9.19	3.97	3.88
12:00	9.09	4.07	3.85
13:00	9.20	3.84	3.89
14:00	9.32	4.25	3.89
15:00	9.22	4.21	3.90
16:00	9.14	3.71	3.91
17:00	9.24	3.89	3.88
18:00	9.66	4.14	3.86
18:00	9.28	4.24	3.88
19:00	9.66	4.14	3.86
20:00	9.55	4.19	3.88
21:00	9.58	3.69	3.89
22:00	9.79	3.65	3.90
23:00	9.82	3.46	3.91

IV. Conclusions and Recommendations

This hazardous materials flow analysis is an important first step in preparing for future incidents involving hazardous materials. In this study we collected placard and vehicle manifest survey data to determine the frequency, type, and amount of hazardous materials traveling through South Carolina's Upstate region. The following are some of the initial conclusions from this survey.

- There is considerable intra-state hazmat traffic especially on I-385 and I-26. This is evidenced by multiple short-haul trips primarily involving gasoline transport.
- Interstate 85 serves as an interstate corridor for hazmat haulers who primarily originate in Georgia with destinations in North Carolina and elsewhere. With the exception of Lavonia, Georgia (Autozone), there were few destinations within South Carolina.
- Hazardous materials flows are greatest on Wednesday and Thursdays although there is some variability among the interstates. Both truck and hazmat traffic are lowest on the weekend.
- Flammable, combustible liquids (Class 3) and gases (Class 2) are the most frequent materials transported both by weight and frequency.

Although this study provides valuable information on hazardous materials flow through a portion of South Carolina, there are several ways to expand our knowledge base. In addition to expanding the areal coverage (include the coastal region, the Midlands, the I-95 corridor), it might be useful to examine the historical data on transportation hazmat incidents in South Carolina to assess their location (which interstate segment) and frequency of occurrence.

VI. References

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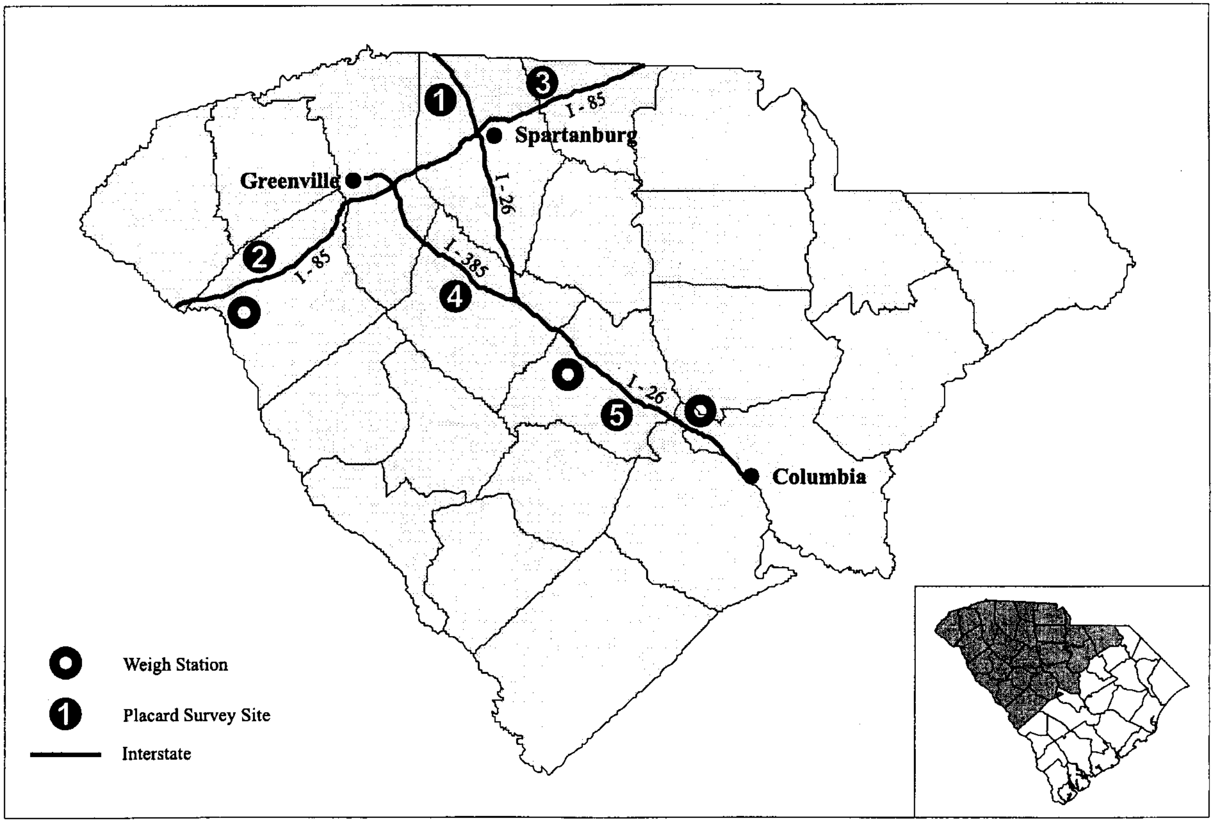


Figure 1 **Study Area and Data Collection Sites**

Figure 2. Hourly Frequency of 18 Wheelers and Hazmats by Interstate

Figure 2a. Hourly Frequency of 18 Wheelers*

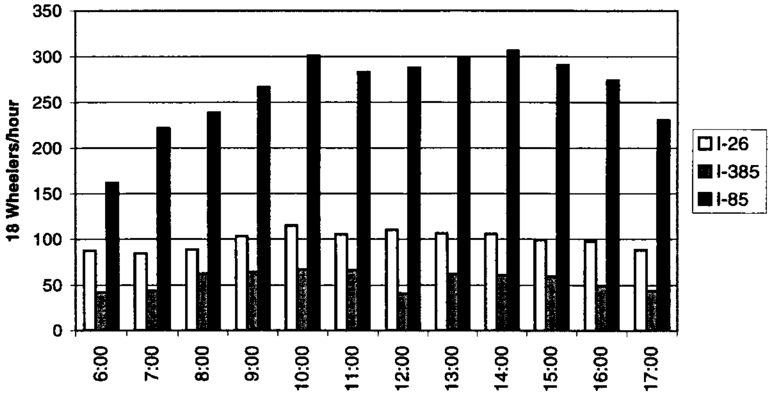
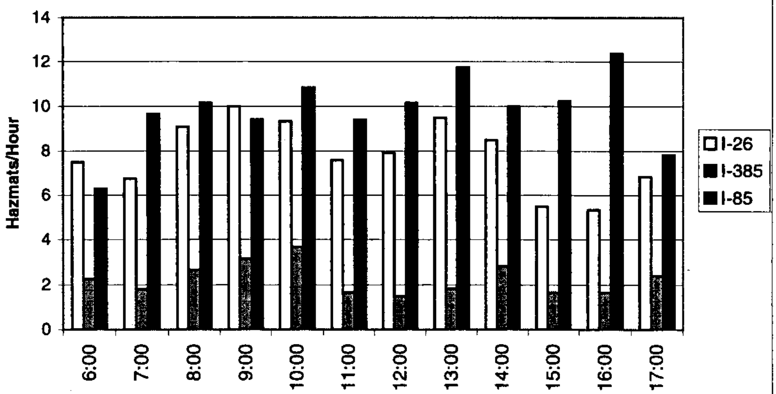


Figure 2b. Hourly Frequency of Hazmats*



* Excludes weigh station counts

Figure 3 Frequency of 18 Wheelers and Hazmats by the Hour

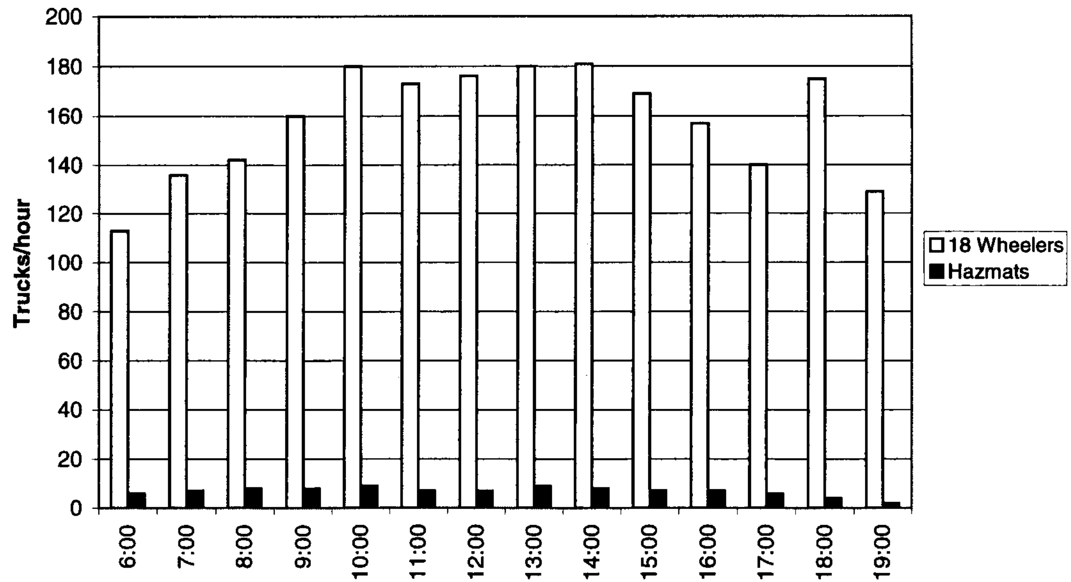


Figure 4 Hourly Ratio of Hazmats to Total Trucks on I-26*

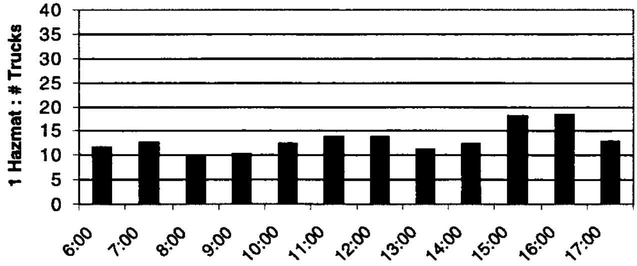


Figure 5 Hourly Ratio of Hazmats to Total Trucks on I-85*

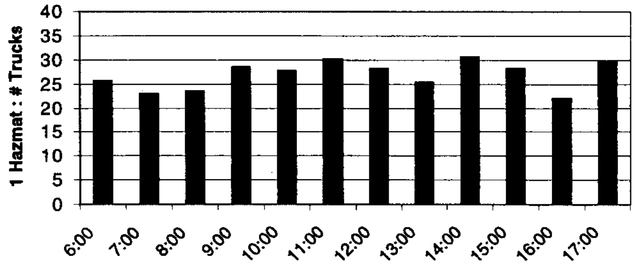
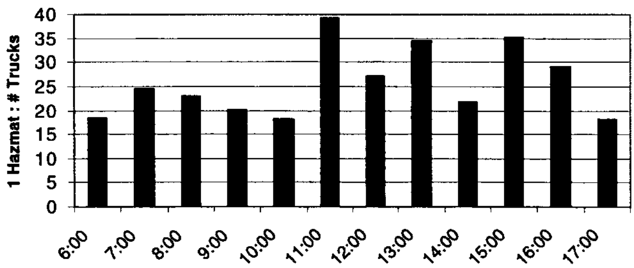


Figure 6 Hourly Ratio of Hazmats to Total Trucks on I-385*



* Excludes weigh station counts

Figure 7. Weekly Frequency of 18 Wheelers and Hazmats by Interstate

Figure 7a. Weekly Frequency of 18 Wheelers*

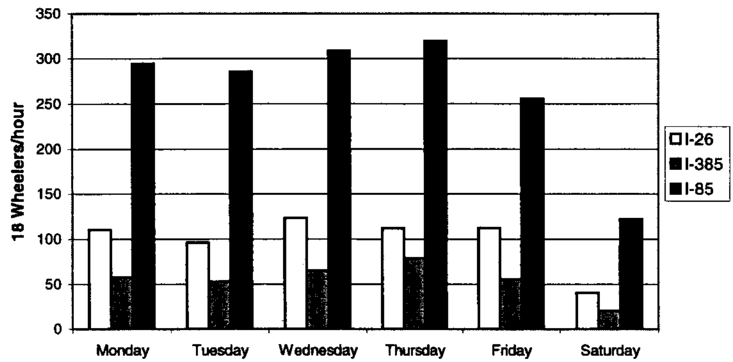
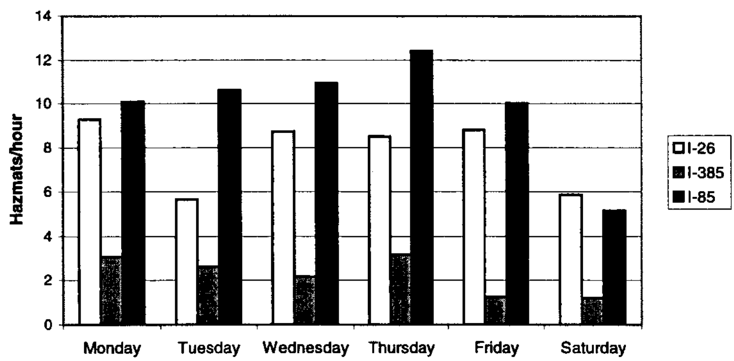
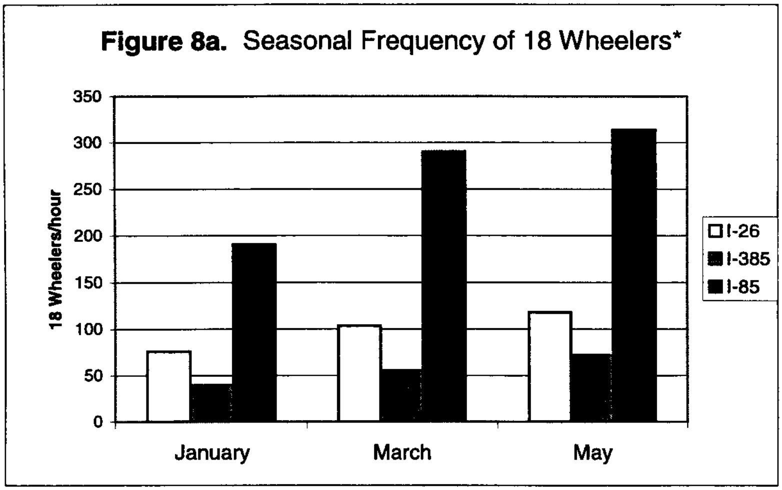


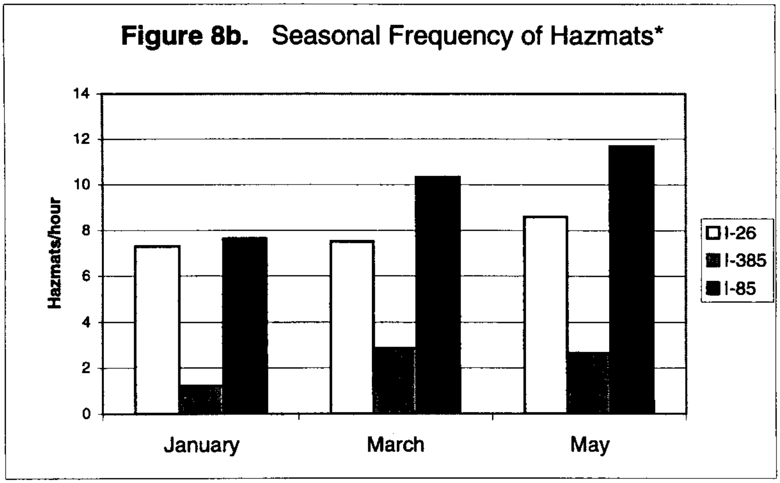
Figure 7b. Weekly Frequency of Hazmats*



* Excludes weigh station counts

Figure 8. Seasonal Frequency of 18 Wheelers and Hazmats by Interstate





* Excludes weigh station counts

Figure 9 Seasonal Frequency of 18 Wheelers and Hazmats

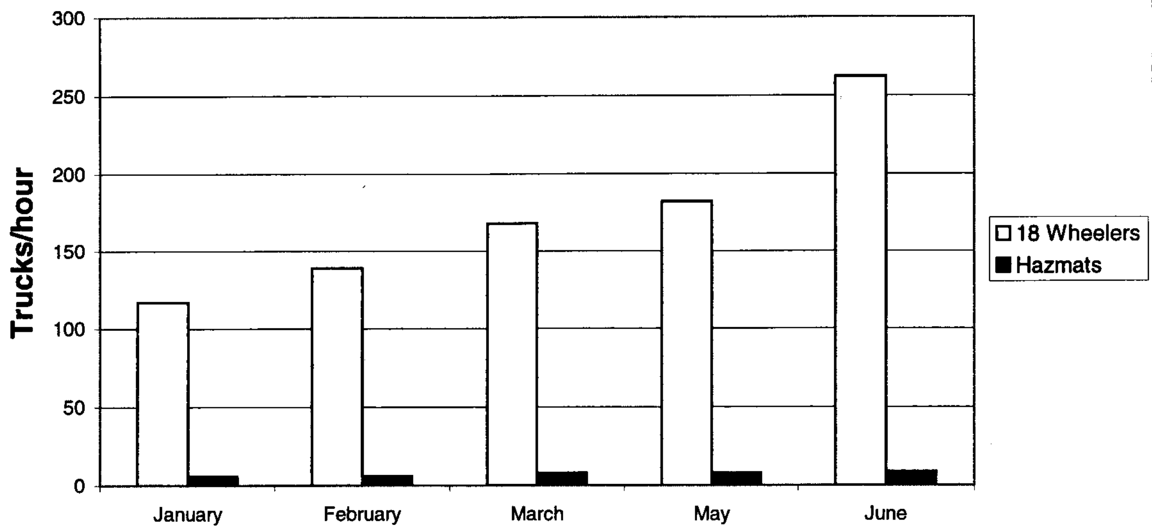
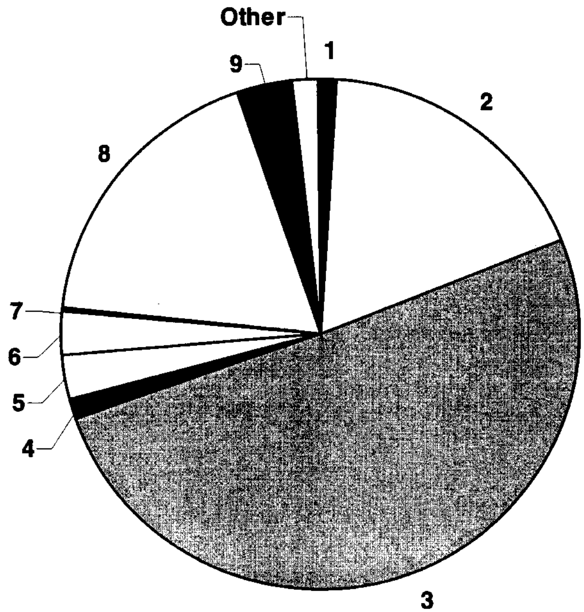


Figure 10 Total Class Frequencies



HAZARD CLASSIFICATION SYSTEM

Class 1: Explosives
Class 2: Gases
Class 3: Flammable Liquids
Class 4: Flammable Solids, Spontaneously Combustible, and Dangerous When Wet Materials
Class 5: Oxidizers and Organic Peroxides
Class 6: Toxic Materials and Infectious Substances
Class 7: Radioactive Materials
Class 8: Corrosive Materials
Class 9: Miscellaneous Dangerous Goods

Figure 11 Hazmat Class Frequencies on I-26

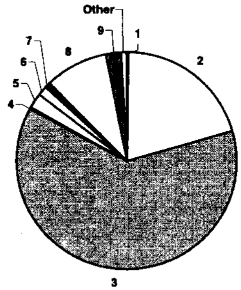
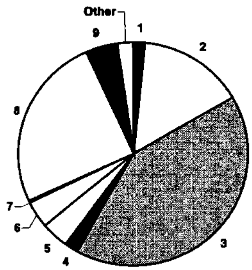


Figure 12 Hazmat Class Frequencies on I-85



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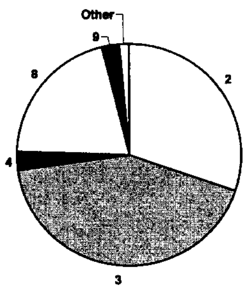
Class 6: Toxic Materials and Infectious Substances
Class 7: Radioactive Materials
Class 8: Corrosive Materials
Class 9: Miscellaneous Dangerous Goods

Figure 13 Hazmat Class Frequencies on I-385



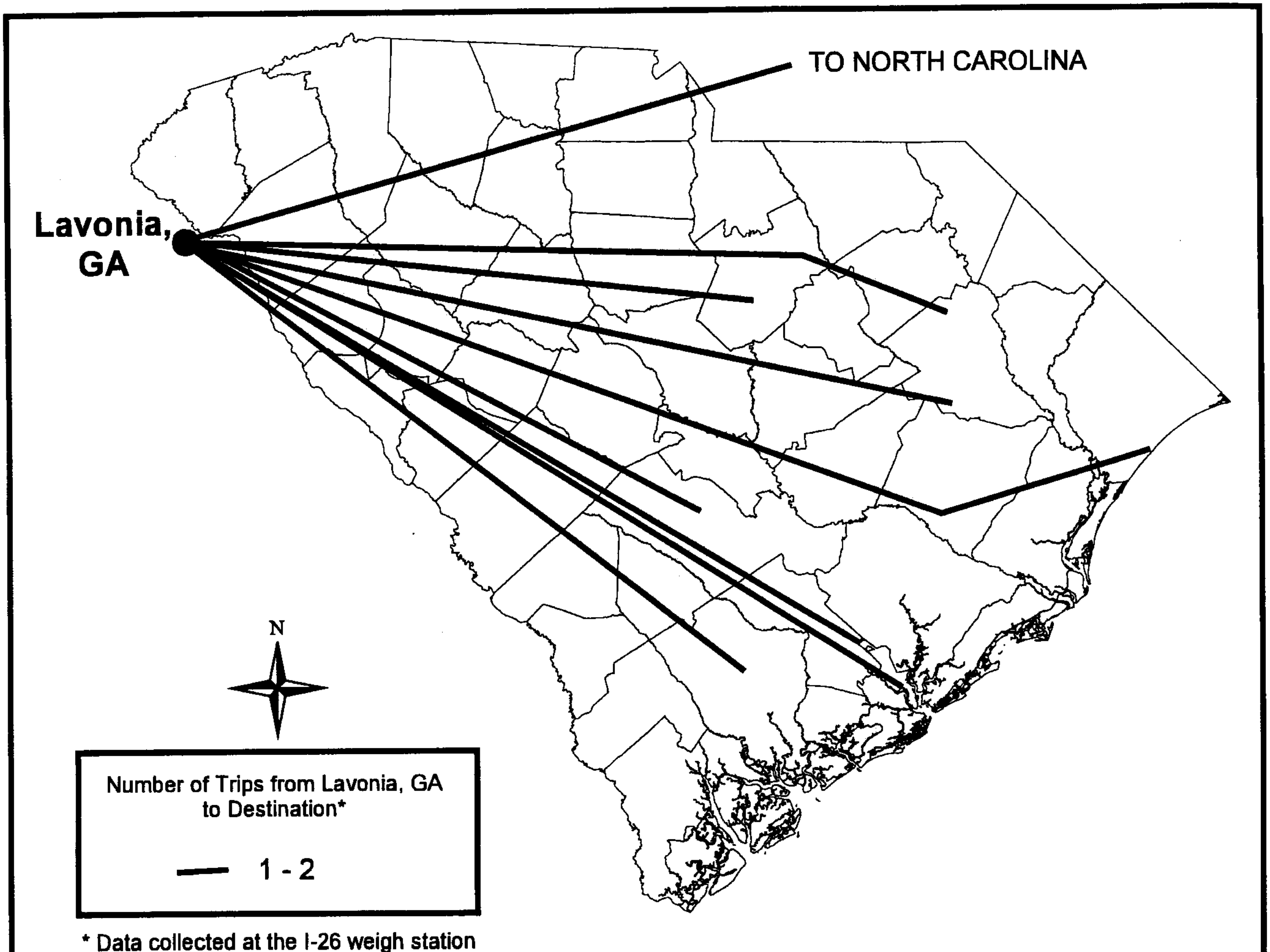


Figure 14. I-26 Weigh Station Origin: Lavonia, GA

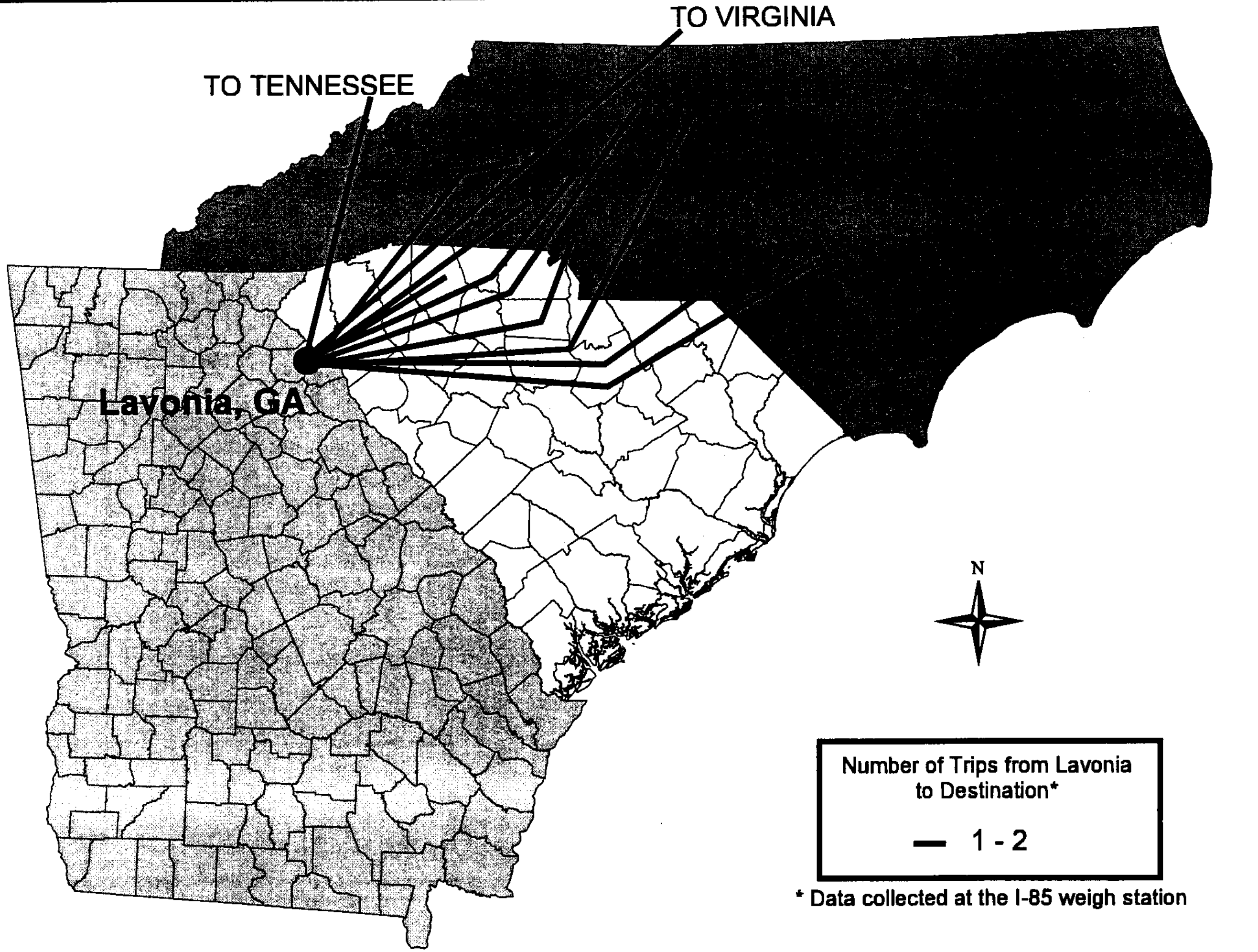
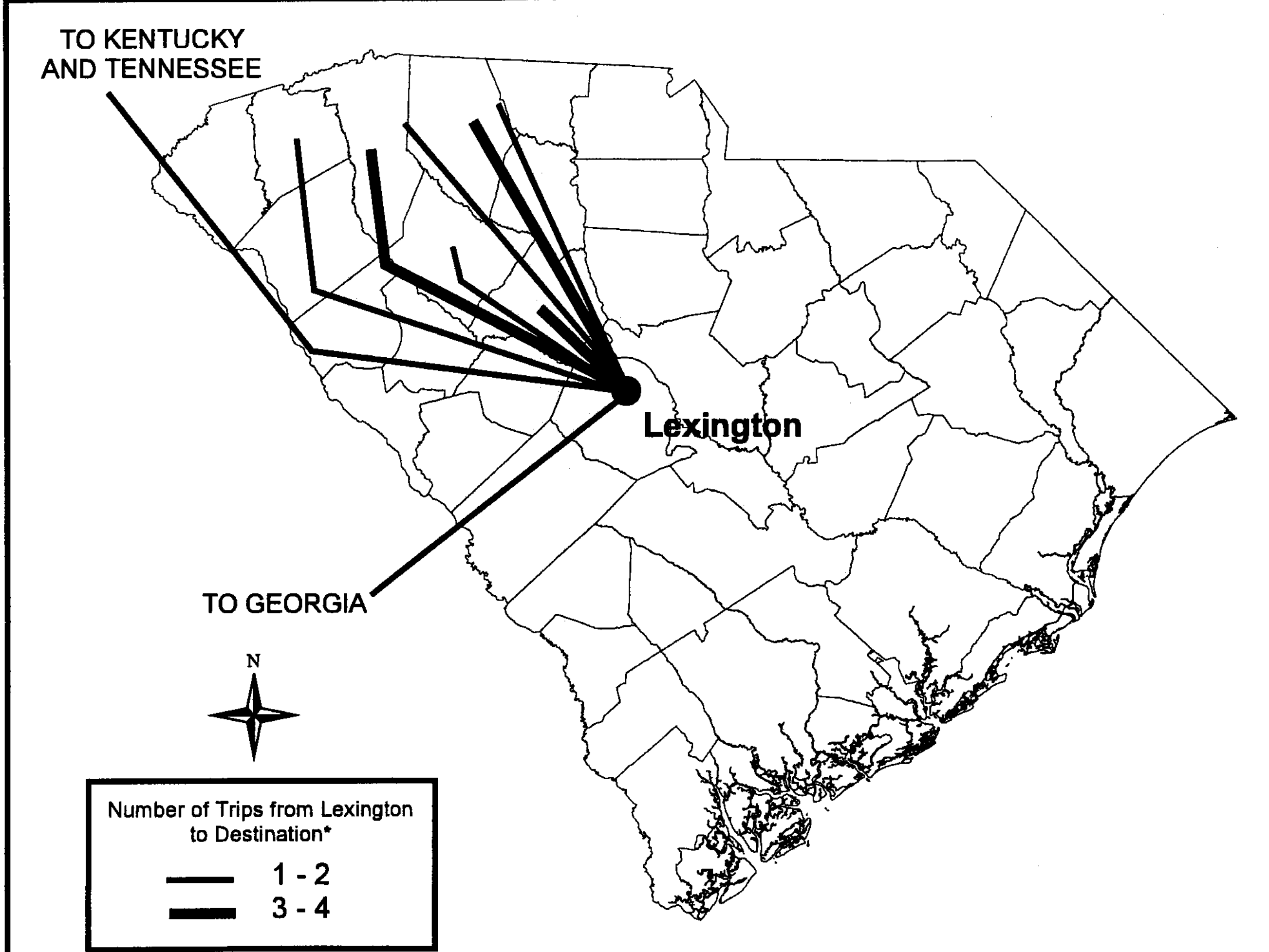


Figure 15. I-85 Weigh Station Origin: Lavonia, GA



* Data collected at the I-26 weigh station

Figure 16. I-26 Weigh Station Origin: Lexington

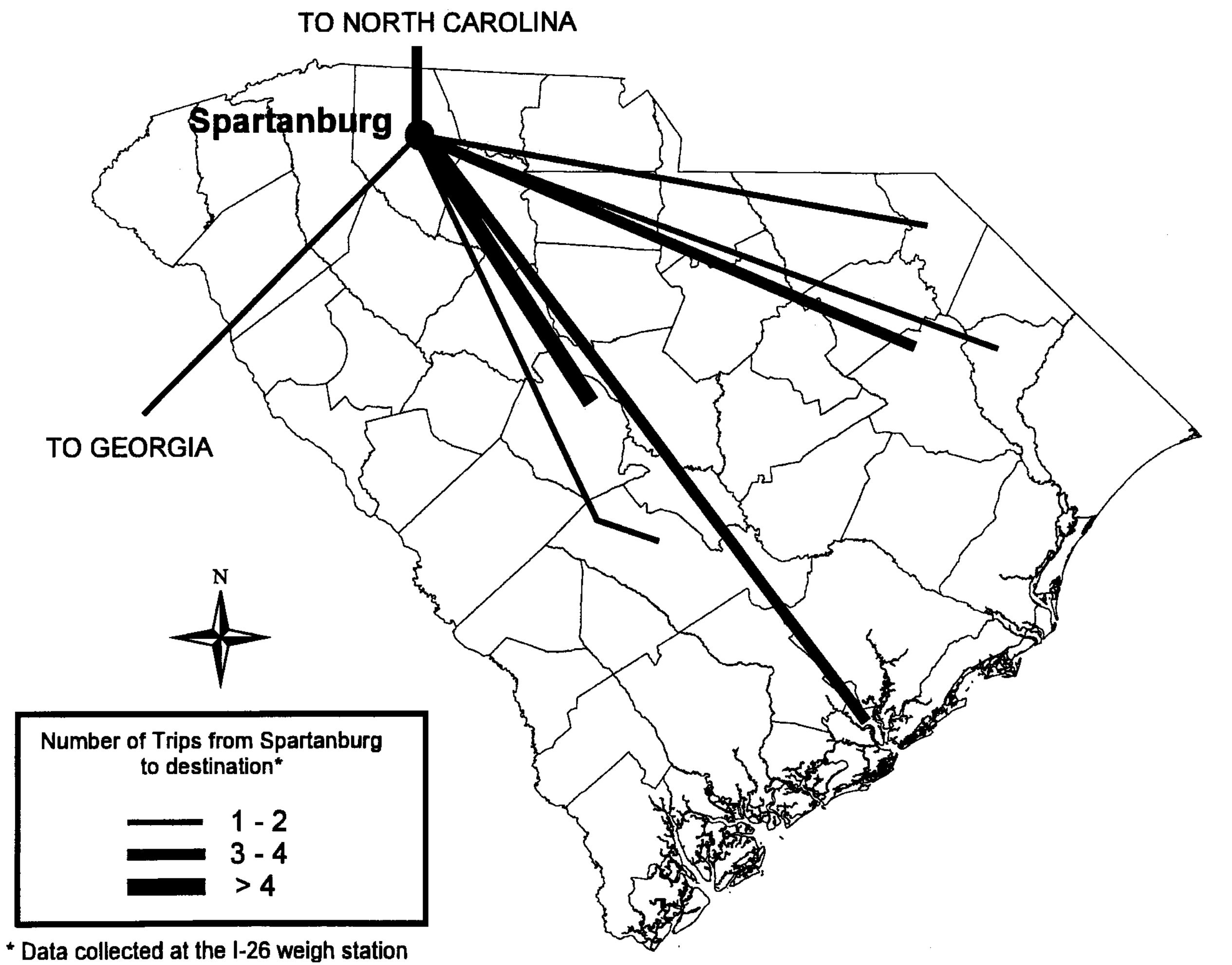


Figure 17. I-26 Weigh Station Origin: Spartanburg

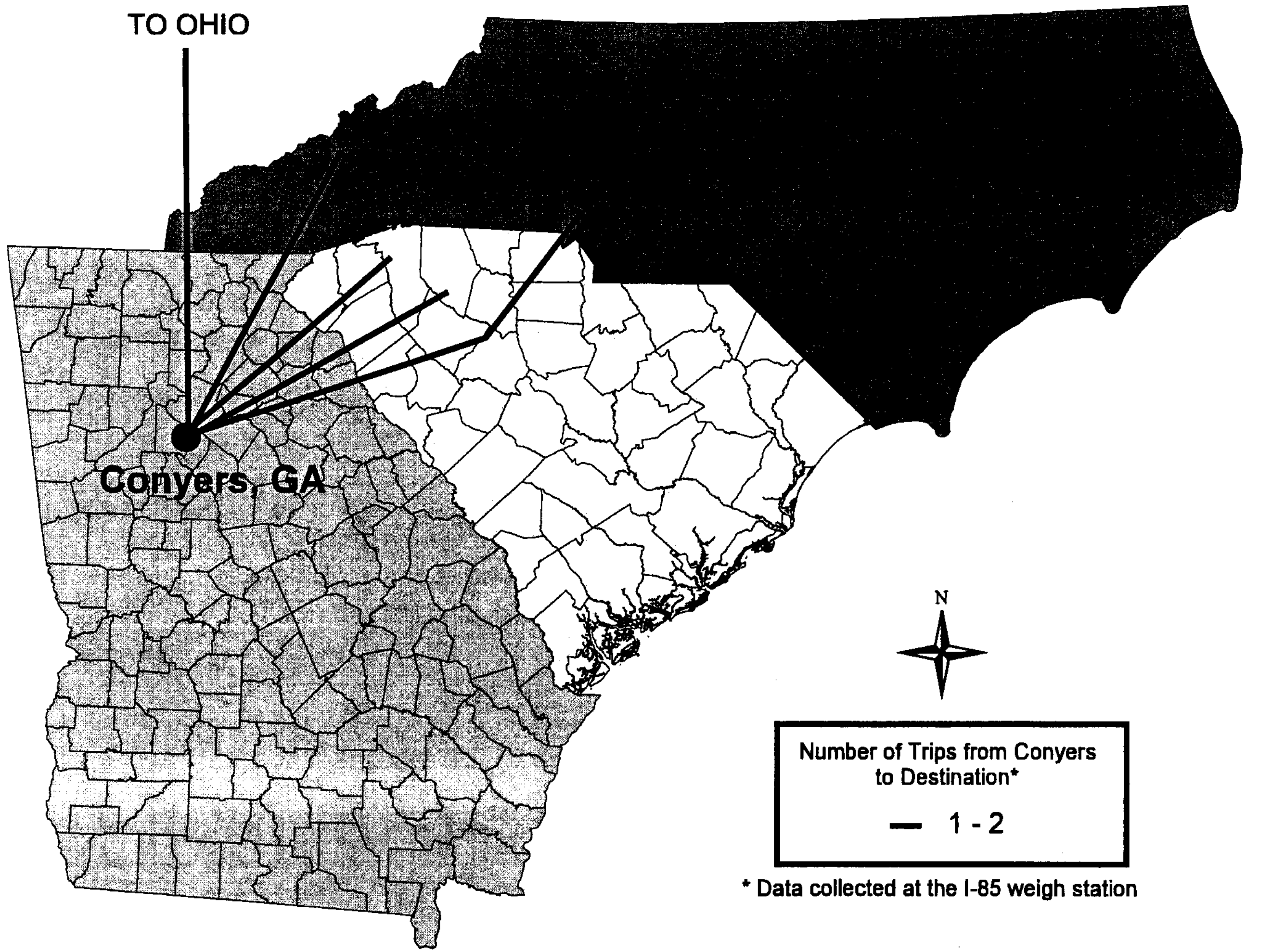


Figure 18. I-85 Weigh Station Origin: Conyers, GA

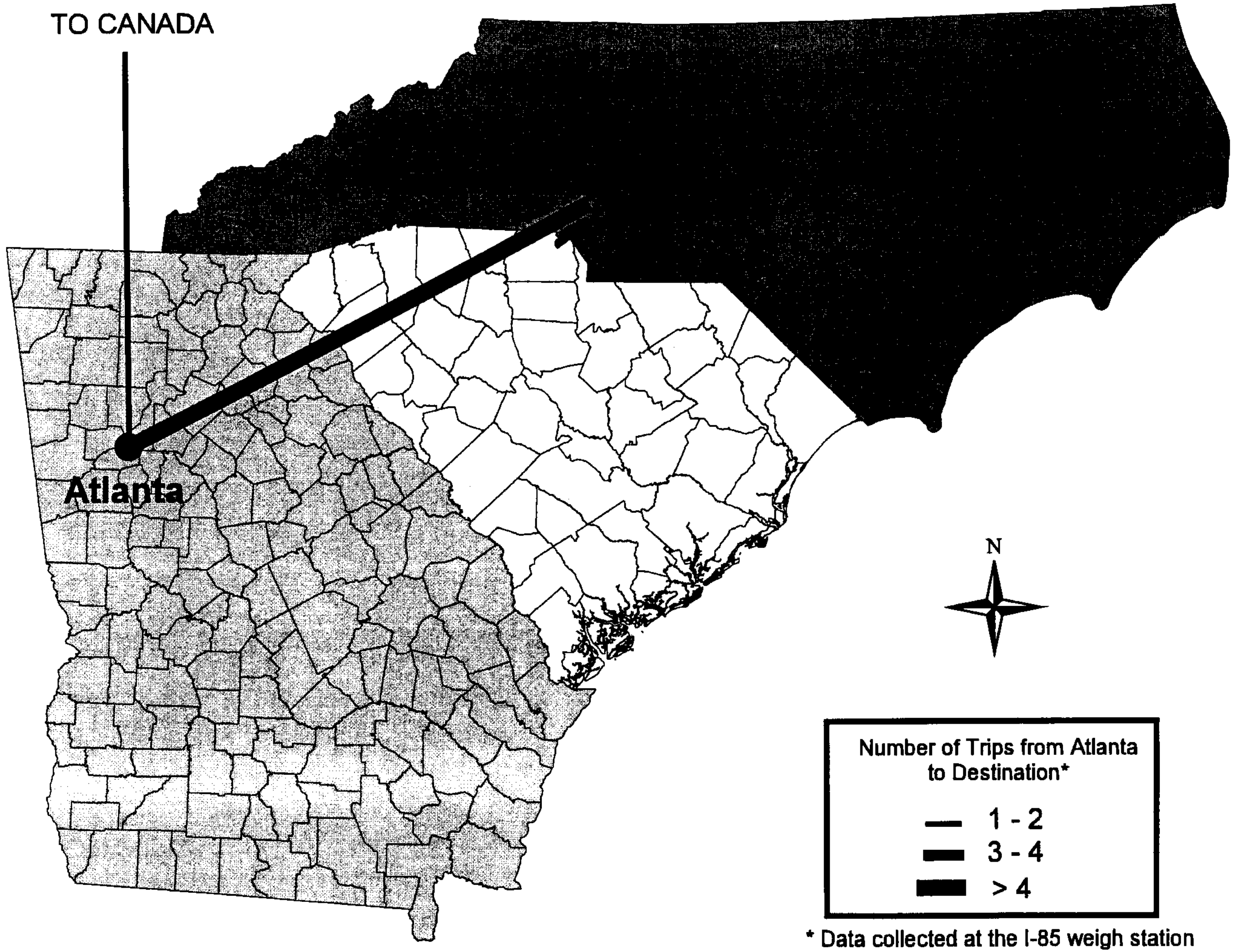


Figure 19. I-85 Weigh Station Origin: Atlanta, GA

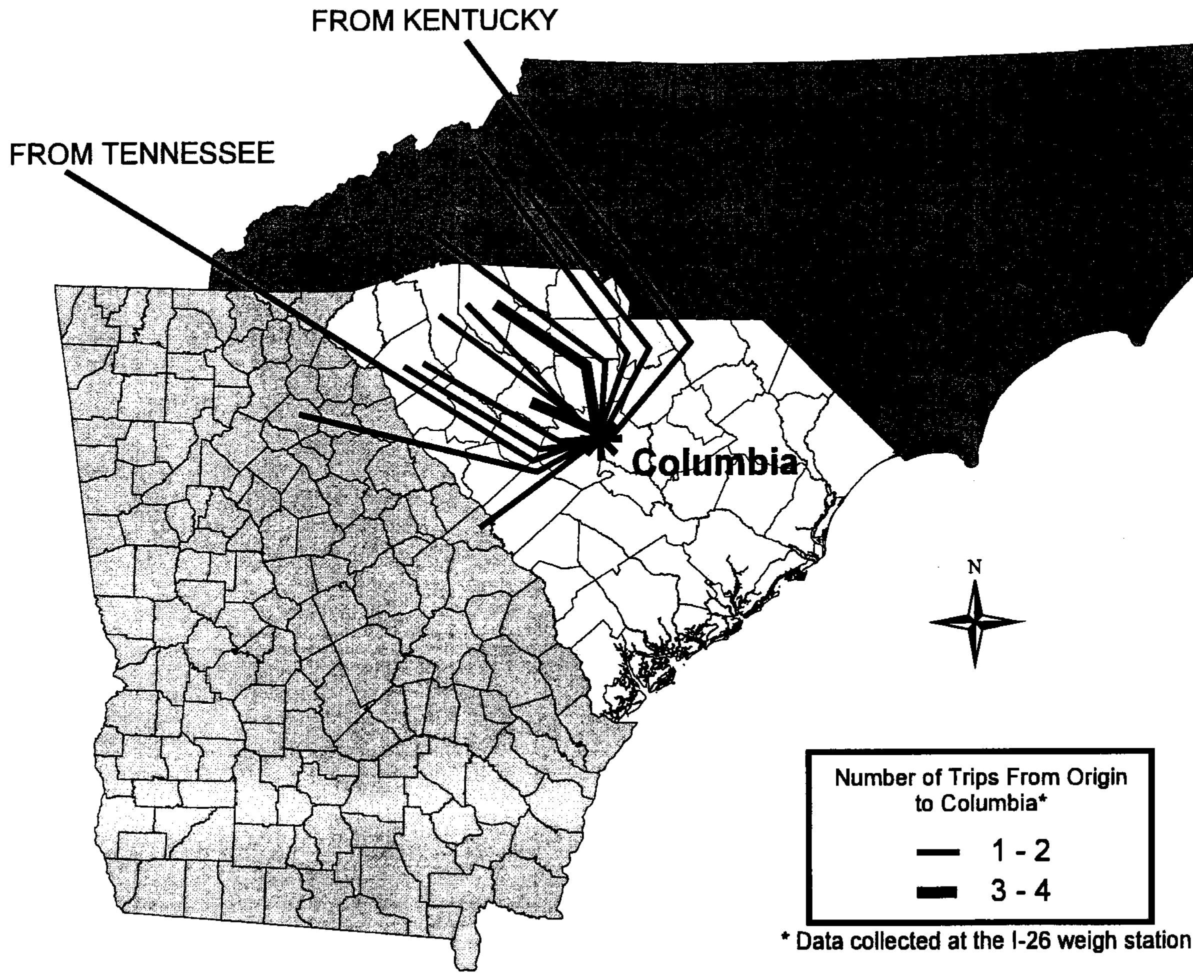


Figure 20. I-26 Weigh Station Destination: Columbia

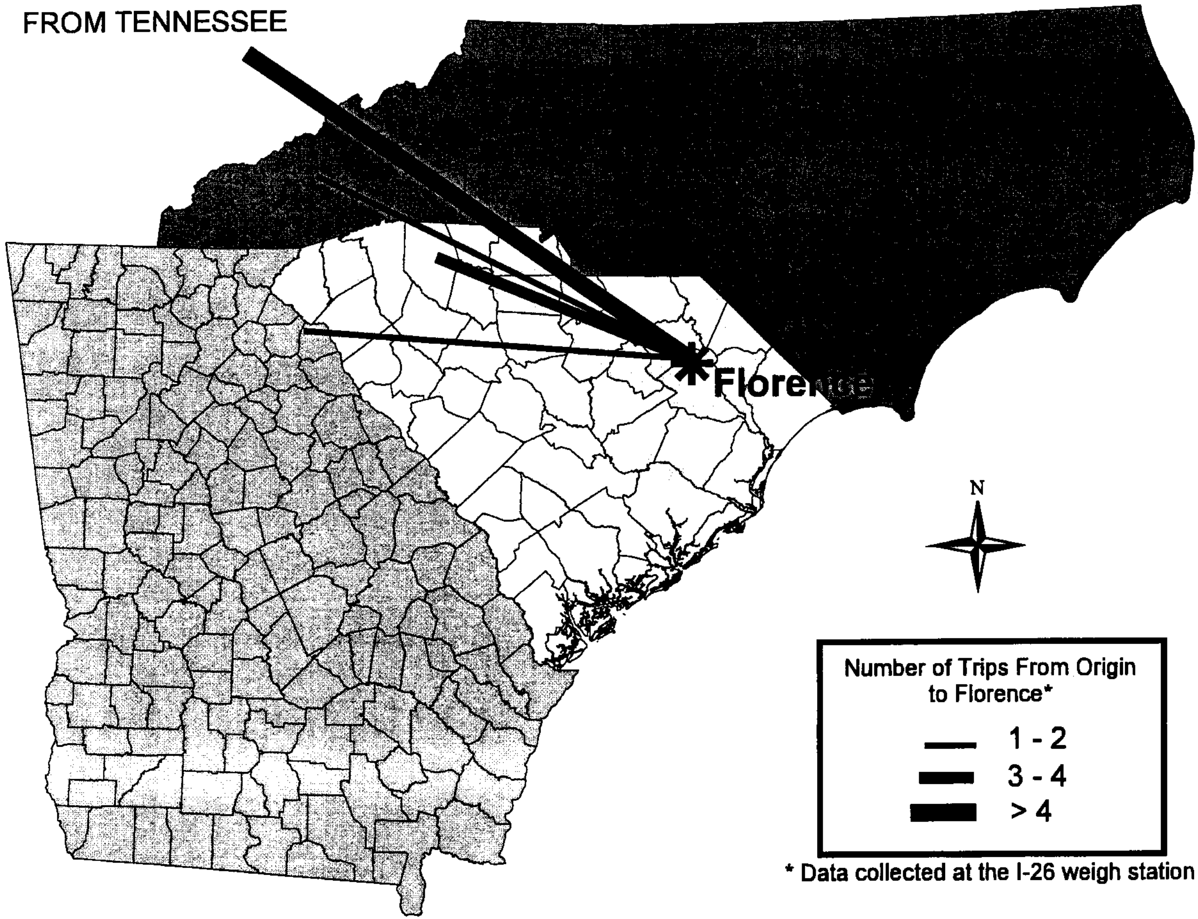


Figure 21. I-26 Weigh Station Destination: Florence

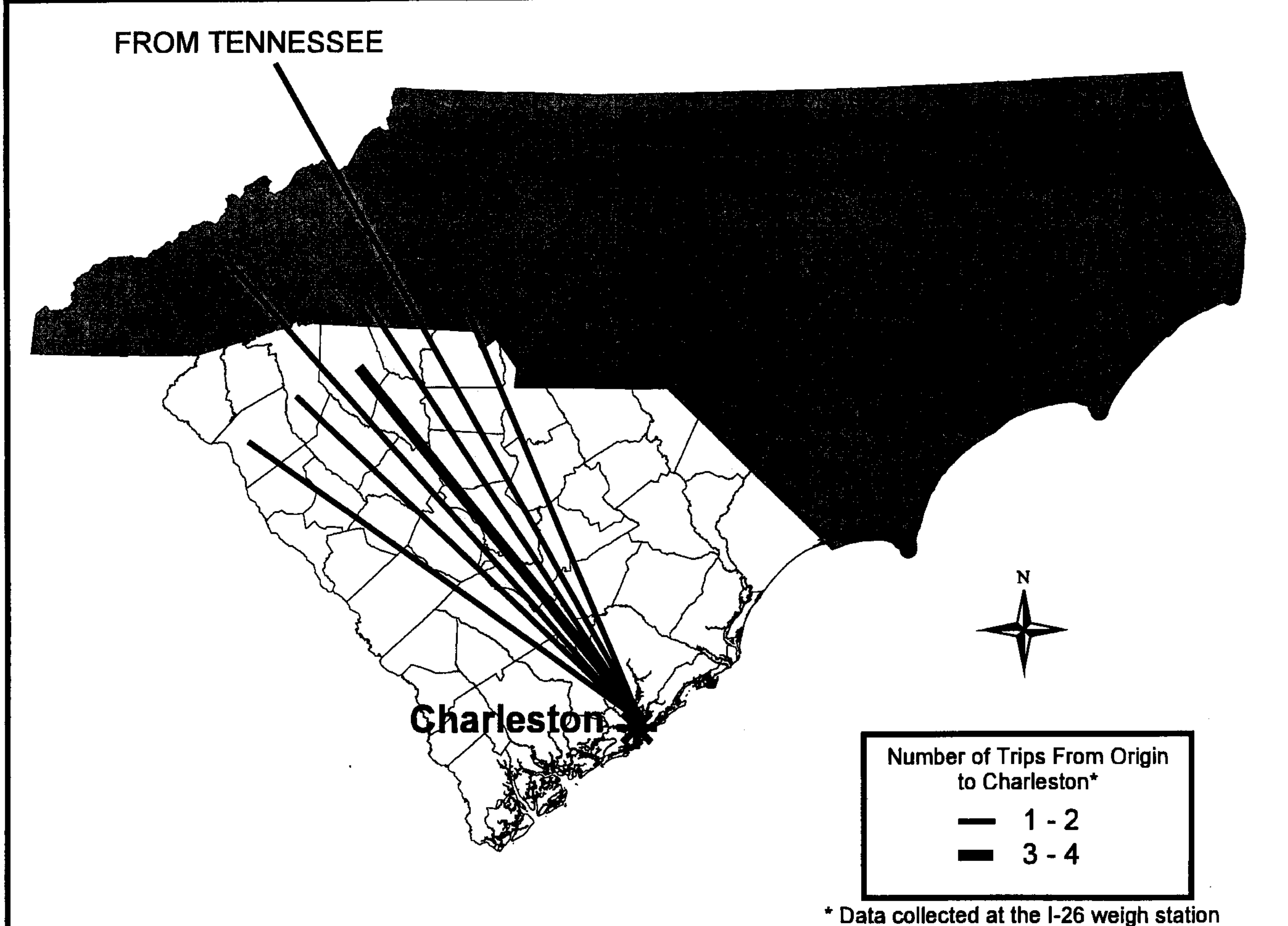


Figure 22. I-26 Weigh Station Destination: Charleston

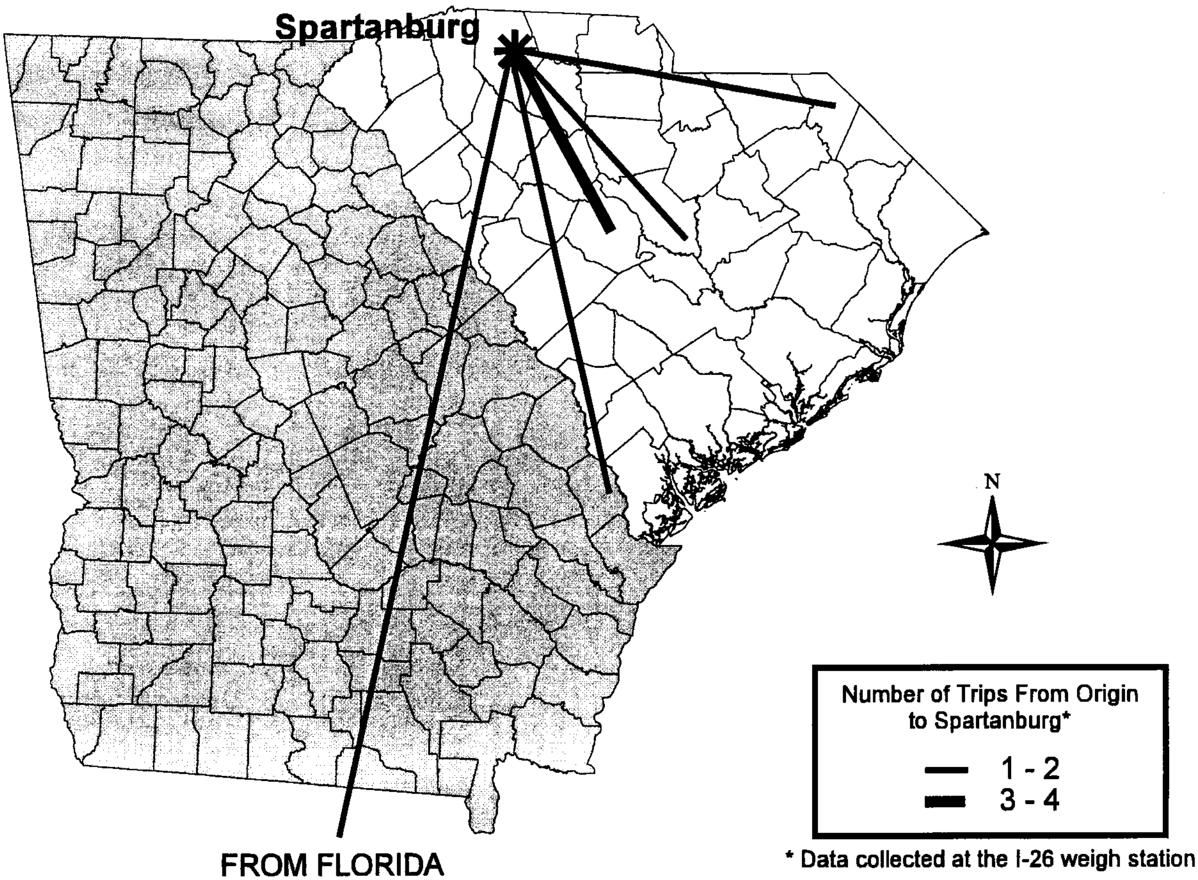


Figure 23. I-26 Weigh Station Destination: Spartanburg

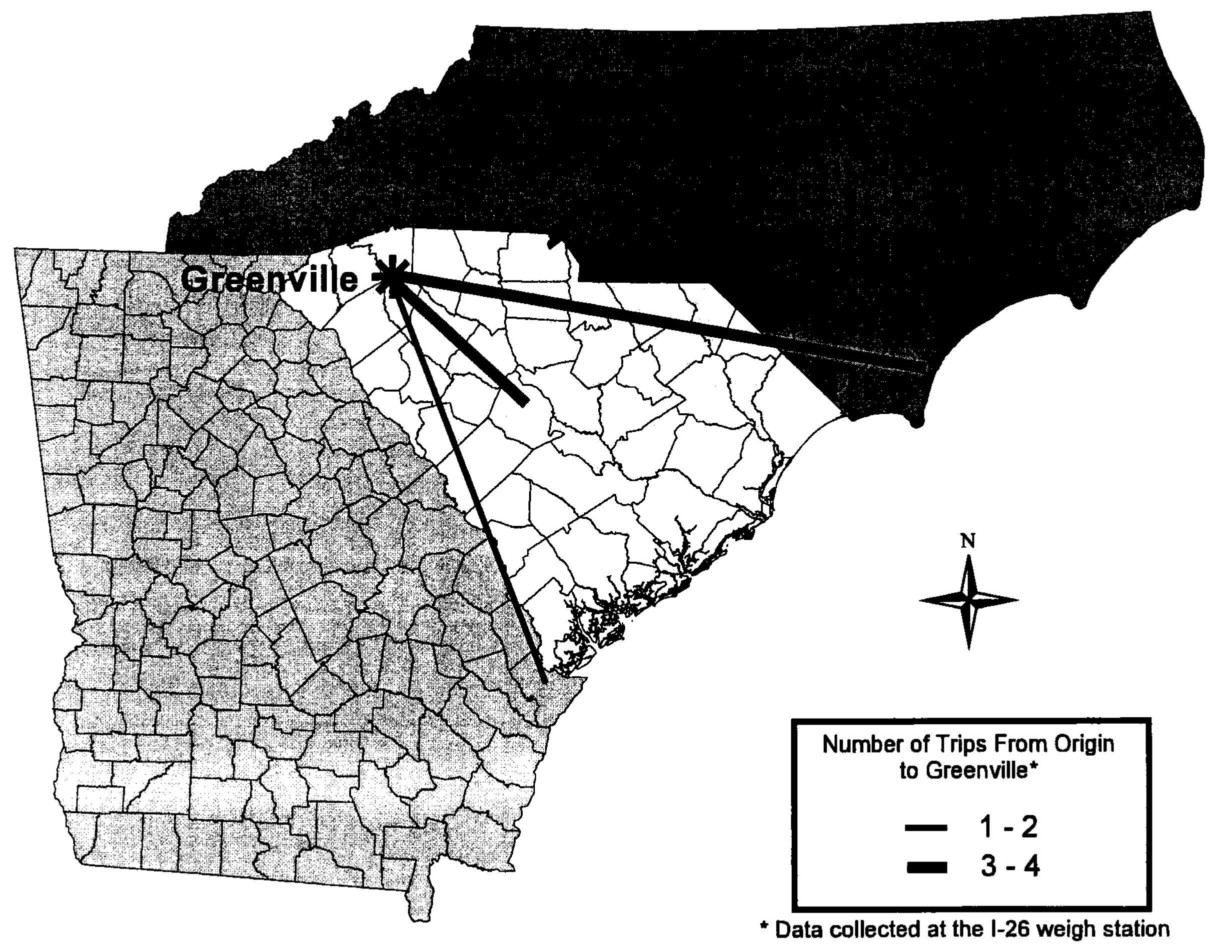


Figure 24. I-26 Weigh Station Destination: Greenville

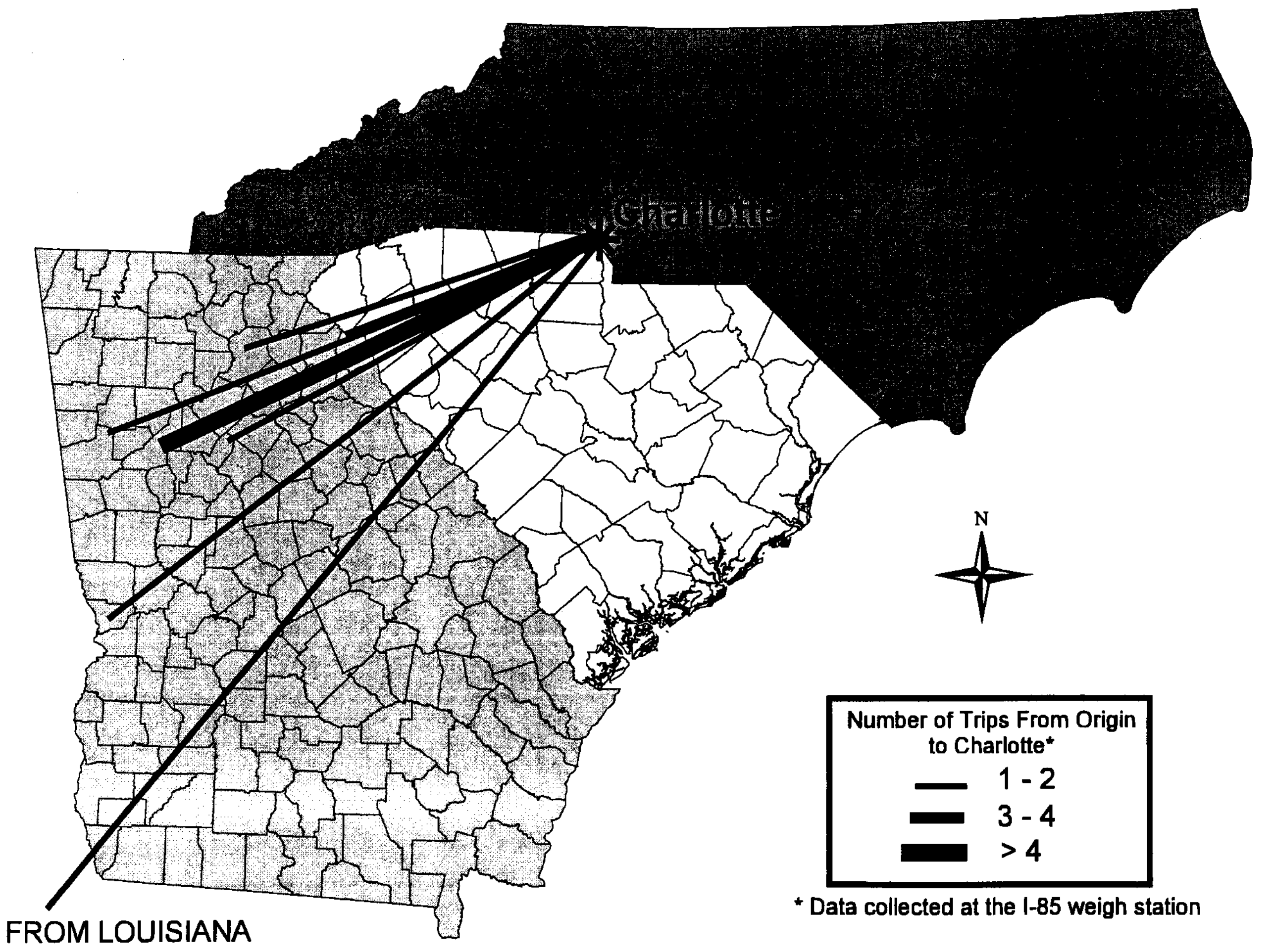


Figure 25. I-85 Weigh Station Destination: Charlotte

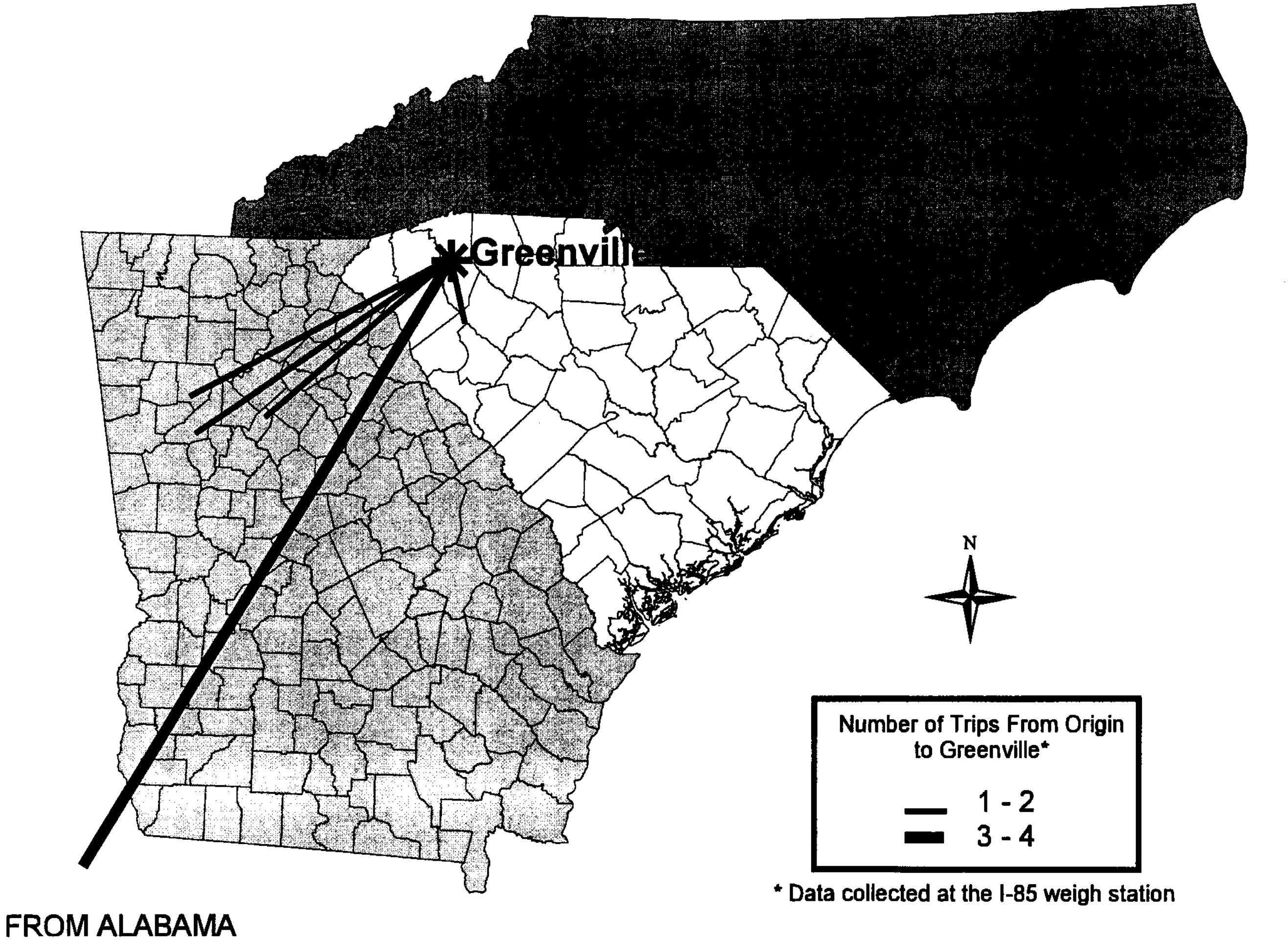


Figure 26. I-85 Weigh Station Destination: Greenville

Figure 27. Extrapolated Hazmat Frequencies